AD-A176 182 A QUICK LOOK AT THE FIRST NRL SHORT PULSE 95 GHZ RADAR FLIGHT DATA(U) NAVAL RESEARCH LAB WASHINGTON DC C S LIN ET AL 12 DEC 86 NRL-MR-5891 1/1

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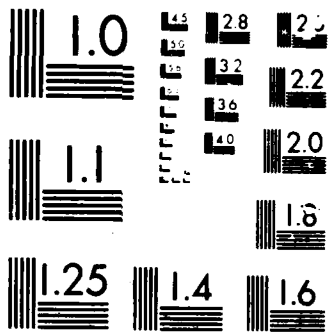
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A Quick Look at the First NRL Short Pulse 95 GHz Radar Flight Data

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Plasma Physics Division

This work was sponsored by the Office of Naval Research.

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NRL Memorandum Report 5891	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Research Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Washington, DC 20375-5000	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Office of Naval Research 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Arlington, VA 22217	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 61153N32 / PROJECT NO. RR032-08-41 / TASK NO. / WORK UNIT ACCESSION NO. DN093-000

11. TITLE (Include Security Classification)
A Quick Look at the First NRL Short Pulse 95 GHz Radar Flight Data

12. PERSONAL AUTHOR(S)
Lin, C.S. and Miller, A.C.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
	FROM ____ TO ____	1986 December 12	16

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	95 GHz, Altimeter, High speed data acquisition system, Short pulse mode, Long pulse mode

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A new high resolution 95 GHz radar system was incorporated into an existing high speed data acquisition system and installed on a NRL RP-3A aircraft. The radar can be operated in either short pulse mode (pulse width 10 nanoseconds) or long pulse mode (pulse width 50 nanoseconds). The high speed data acquisition system can sample the radar return waveforms with total data burst rate of up to 500 KHz.

A series of measurements were made over the Great Dismal Swamp and the Atlantic Ocean. The radar was deployed in the Altimeter mode during the Dismal Swamp measurements, while both the Altimeter and Aft-looking mode were deployed over the ocean. Representative data are presented.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL C.S. Lin	22b. TELEPHONE (Include Area Code) (202) 767-2663 / 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

*U.S. Government Printing Office: 1985-507-047

CONTENTS

A QUICK LOOK AT THE FIRST NRL SHORT PULSE 95 GHZ RADAR FLIGHT DATA

1.0 INTRODUCTION

A new short pulse 95 GHz radar system was flown on the NRL research aircraft RP-3A 149670 on 19-20 December 1985 and a series of 25 measurements were made over both land and ocean. A few of the measurements made on 20 December were in coincidence with the NRL GEOSAT underflight program.

This report will summarize these measurements, the experimental configurations, and some preliminary results.

2.0 THE 95 GHZ RADAR

The 95 GHz radar was designed by the Georgia Institute of Technology and delivered to NRL in May 1985. A description of this radar is given in the final report and instruction manual (1) prepared by Georgia Tech. The system parameters are taken from this manual and shown in Table 1 for ready reference.

TABLE 1. SYSTEM PARAMETERS

Transmit Power	1 kW peak
Antenna Gain	45 dB
Beamwidth	1° pencil
Frequency	94 GHz
Noise Figure	9.6 dB
Bandwidth	500 MHz
System Losses	5.7 dB
Atmospheric Losses	0.5 dB/km
Pulse Width	5-10 or 50 ns
Pulse Repetition Frequency (PRF)	10.2 kHz
Polarization	Vertical
IF Frequency	3 GHz
Dynamic Range	40 dB - Instantaneous 60 dB - Total

After several extensive test runs of the radar in the laboratory at NRL, it was determined that in order to improve reliability, the grid bias of the EIO tube had to be adjusted lower. This adjustment produced an increase in the pulse width of the short pulse mode to between 5 and 10 nanoseconds.

During flight, the radar was deployed at the altitudes between 550 feet and 9000 feet. The resulting footprint was between 10 and 160 feet in diameter, with the radar pencil beamwidth of one degree.

Manuscript approved September 12, 1986.

Although the radar pulse rate was 10 KHz, the data acquisition system only collected data on one pulse in every 10 without averaging due to data throughput considerations.

3.0 DATA ACQUISITION SYSTEM

A description of the basic data acquisition system can be found in reference (2). The 10 KHz radar synch pulse rate was reduced to 1 KHz by a decade counter and the radar video output was fed to a 1 GHz inverting amplifier in order to make the signal compatible with the existing data acquisition system. The sample interval of the BIOMATION 6500 was set at 5 nanoseconds to avoid excessive jitter. The aperture window was 10 nanoseconds.

4.0 EXPERIMENTAL CONFIGURATIONS

The 95 GHz radar was installed on a tiltable pallet in the P3 fairing. The tilt of the pallet can be adjusted from 0 to 45 degrees through a control panel in the aircraft cabin during flight. The radar looks in the aft direction when tilted.

A 100 MHz scope was used to monitor the 10 KHz radar synch pulse, A/D and threshold D/A outputs from the interface circuits, and the radar video return during flight.

Before each experimental run, all these parameters were properly set and monitored. After a satisfactory experimental configuration was selected and stabilized, the real-time data acquisition program was started. This computer program controlled the collection of a fixed number of blocks of data which were then output to magnetic tape.

5.0 EXPERIMENTAL RESULTS

The measurements can be classified into four categories according to the different targets and experimental configurations. They are described in the following paragraphs.

5.1 Terrain - Nadir Looking Configuration

Terrain data were collected over the Great Dismal Swamp with the radar operation in the altimeter mode. The flight path covered a variety of terrain and Lake Drummond. The aircraft altitudes were 600 and 1100 feet. The time of flight of the radar pulses determined the distance between the aircraft and the surface. With a one degree beam, the altimeter became an excellant profilometer.

A 3-D plot of some sample data is shown in Figure 1. The X-axis is the aircraft flight time and the Y-axis is the range of the return radar signals. The third dimension shows the amplitude of the return waveforms. The sample data show return waveforms from plowed fields, wooded areas, and the lake surface.

Detailed examination of Figure 1 shows that trees as tall as six meters were profiled. The data also show good penetration of the 95 GHz energy

through the vegetation canopy. By comparing return amplitudes, it is clear the MM-wave returns from the lake surface were much stronger than those from the other targets.

During the Dismal Swamp overflights, a few simultaneous X-band radar data were also collected. Comparisons of these two data sets will be published in future reports.

5.2 Ocean - Nadir Looking Configuration

The 95 GHz radar system was also used in the altimeter mode over the ocean. A plot of one of the data sets is shown in Figure 2. Again, the X-axis is aircraft flight time, Y-axis is the range, and the third dimension is the return waveform amplitude. The slow undulations are from the aircraft motion, and most of remaining fluctuations are due to the motion of sea surface.

The effective data rates of these measurements were at 250 Hz, with the aircraft speed of 100 m/sec, a measurement was taken at every 0.4 meter. It is expected that a 10 nanosecond radar employed in this configuration should have horizontal resolution of 1 meter and vertical resolution of about 1.6 meters. Again, high resolution analyses of these data sets will follow in future reports.

5.3 Ocean - Off Nadir Configuration

In this configuration, the incidence angle of the radar beam on the ocean surface was varied by varying the tilt of the pallet while the time of flight now determines the slant range. A typical return in the short pulse mode is shown in Figure 3. The large changes in range were due to changes in incidence angle.

A similar plot for the long pulse mode is shown in Figure 4. It should be noted that in the long pulse mode, the transmitted radar pulses had a double peak, which also showed up in the return waveform.

Figure 5 is a plot of the radar return amplitude vs radar incidence angle. A long pulse mode data set is plotted with a short pulse set for comparison. Both data sets were collected at 650 ft altitude. It is clear from this figure that the two data sets show different characteristics. The long pulse return amplitude decreases slowly at increasing incidence angle while the short pulse return amplitude decreases very quickly once the radar is at off nadir angle. More experiments are planned to explain this difference in return characteristics.

5.4 Runway - Nadir Looking Configuration

In order to establish a baseline for the 95 GHz radar as a profilometer, a data run was made over the runway at the Naval Air Station, Patuxent River, Maryland Figure 6 is a plot of radar return signals over the runway. Detailed analyses of the data show near constant range over the runway. The remaining range fluctuations are due to either the radar system jitter or aircraft motion or both. By comparing Figure 6 and Figure 2, it

is clear that the return over the runway is much more uniform than the return over the ocean where the range and amplitude are modulated by the motion of surface wave.

6.0 CONCLUSION

A quick look at this series of flight data shows that the 95 GHz radar system is performing as expected in both the altimeter and aft-looking off nadir modes. The data acquisition system was adequate for these experimental configurations. Detailed analyses of these experimental data will be reported in the near future. These analyses will establish important parameters for the hardware and software design of future short pulse MM-wave radar experiments and systems.

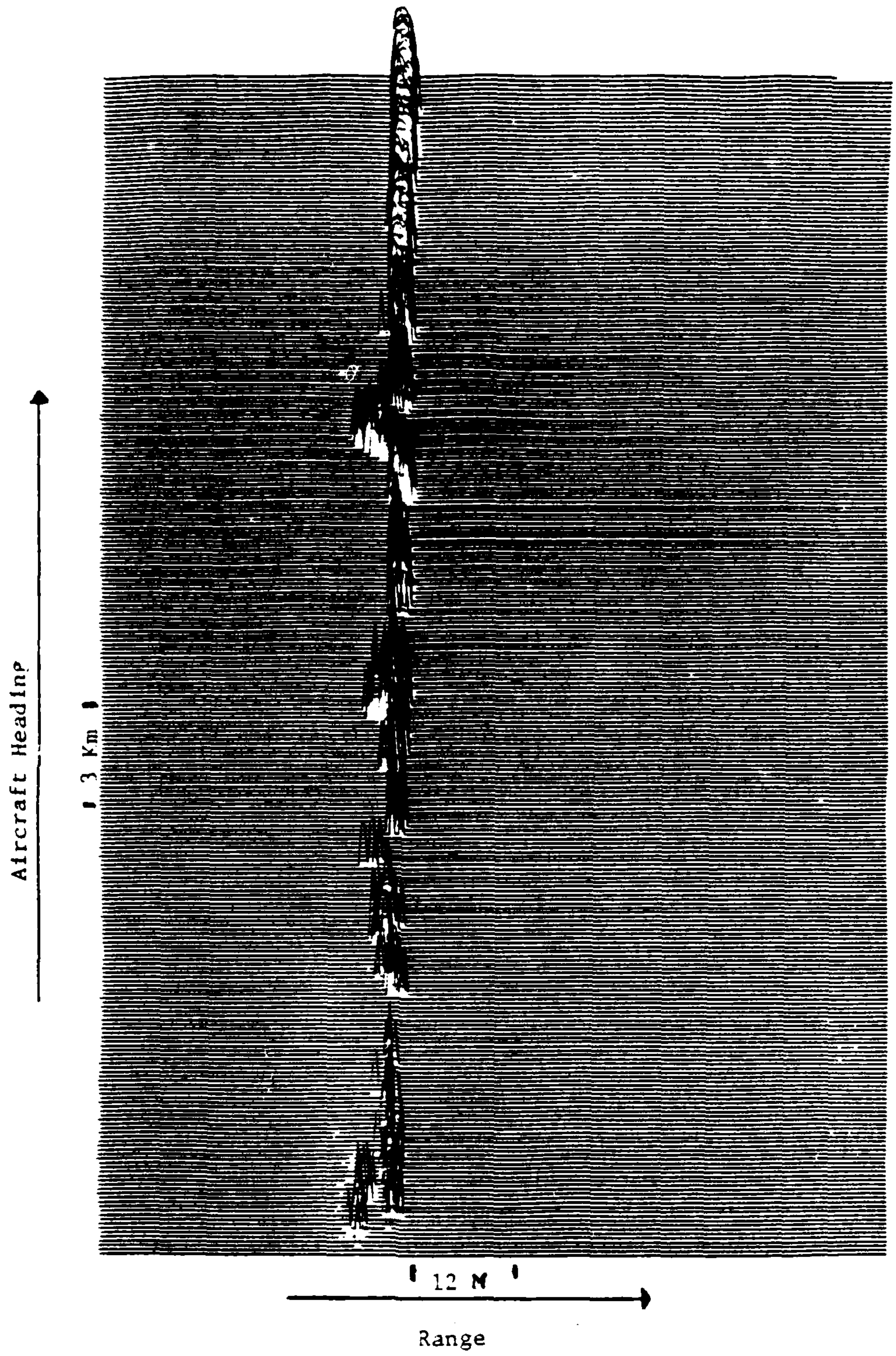

Fig. 1 — Nadir returns over the Great Dismal Swamp

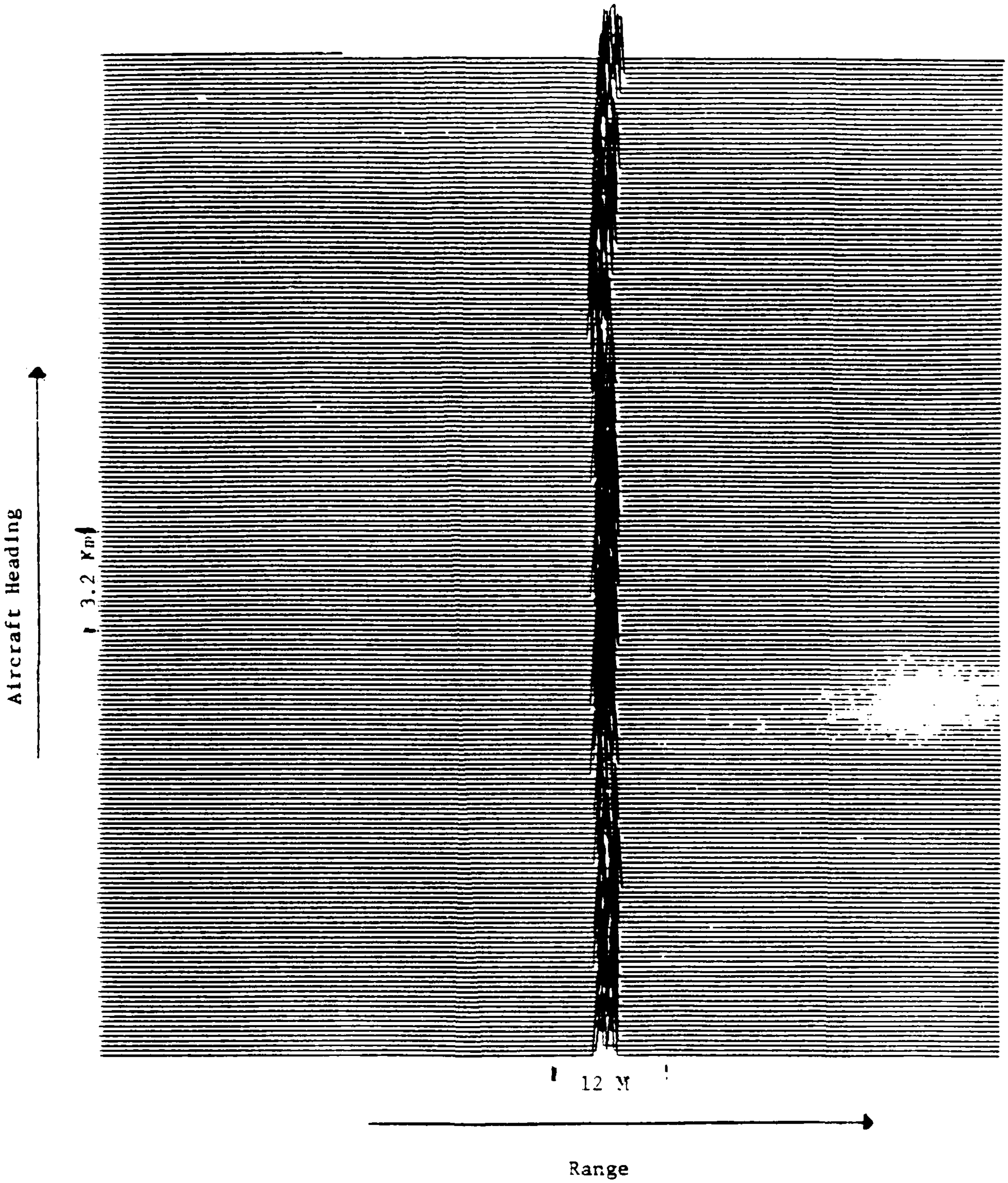

Fig. 2 — Nadir looking returns over ocean

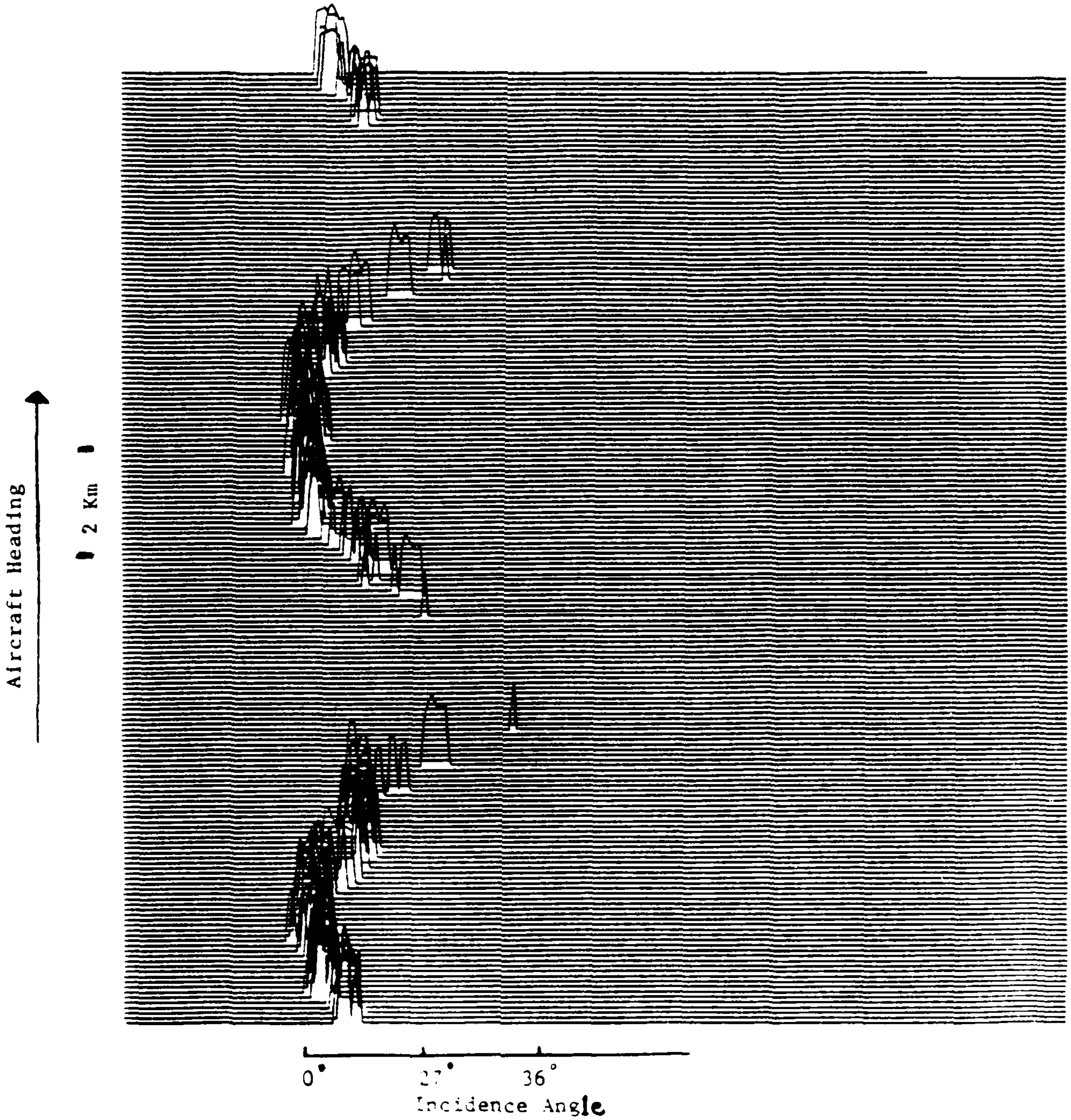

Fig. 3 — Aft-looking return over ocean-short pulse

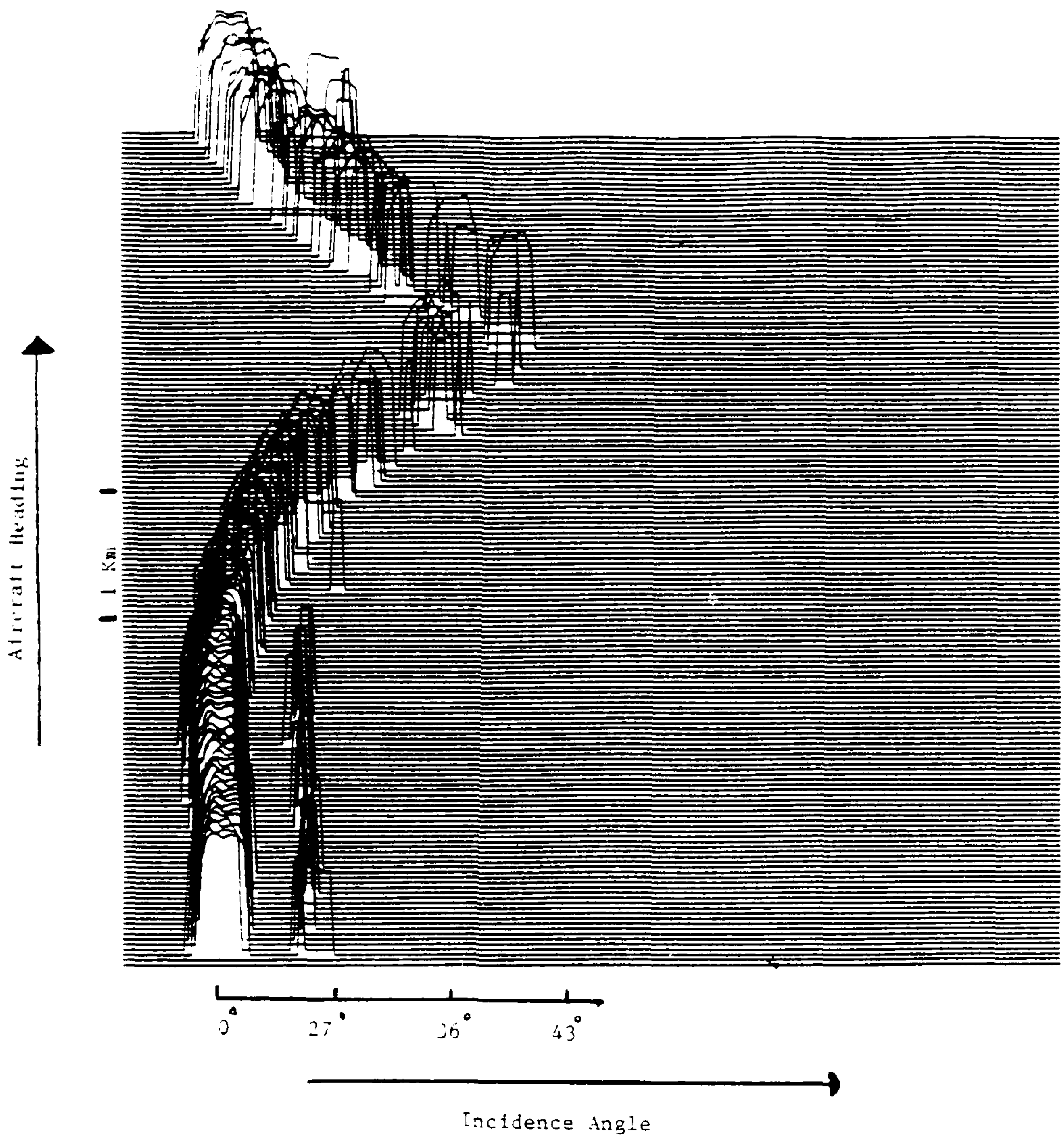

Fig. 4 — Aft-looking returns over ocean-long pulse

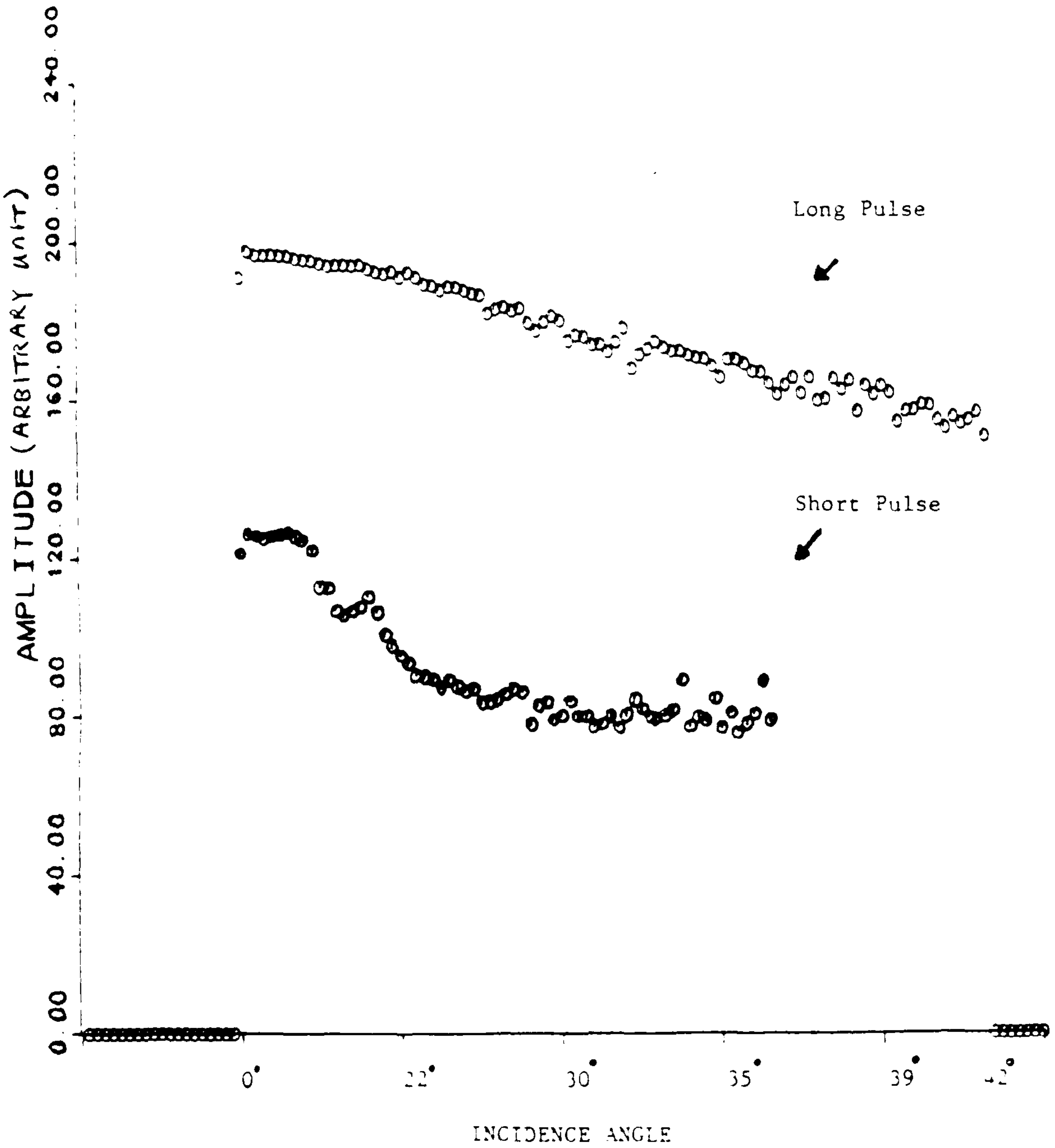

Fig. 5 — Return amplitudes vs incidence angle (long and short pulses)

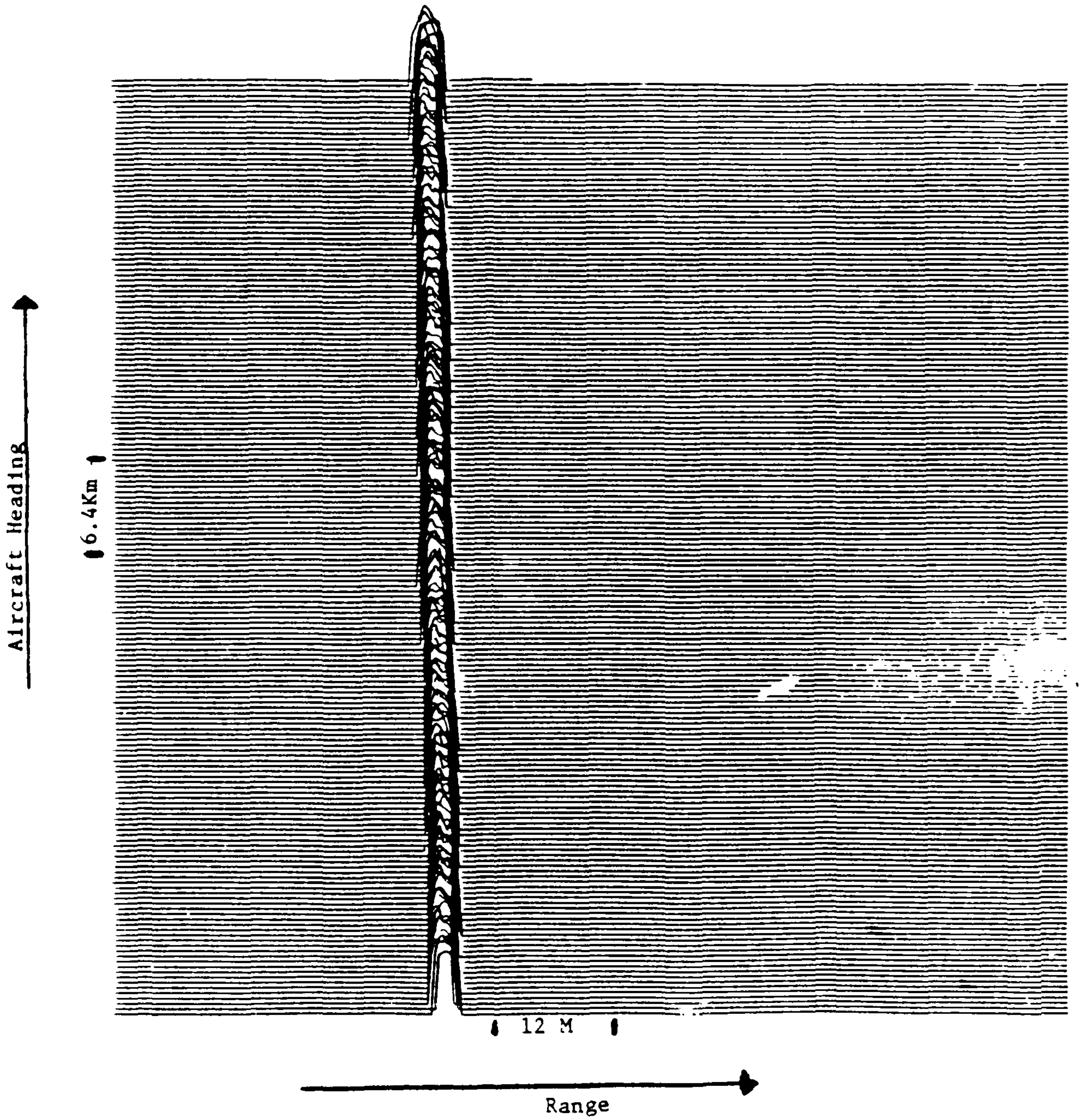

Fig. 6 — Nadir returns over the runway

ACKNOWLEDGMENTS

The data flights were made possible through the excellent support of the NRL Operational Services (Code 1210), CDR J. E. Kirkendall commanding, and the NRL Flight Support Detachment (Code 1280), CDR D. P. Glanzman commanding, at the Naval Air Test Center, Patuxent River. Pete Richardson aided with the installation while Wah Eng kept the radar repaired. The authors would like to thank Mr. Ben Yaplee for many helpful discussions during this work.

This work was sponsored by the Office of Naval Research under grant to the Naval Research Laboratory Subelement: Ocean Geophysics (SE32), Task Area: Surveillance Phenomenology (RR 032-08-41), Work Unit: MM - Wave Scattering (0930).

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